

HARNES, DICKEY & PIERCE, P.L.C.

Attorneys and Counselors
5445 Corporate Drive, Suite 400
Troy, Michigan 48098-2683
Phone: 248-641-1600
Fax: 248-641-0270
St. Louis, MO • Washington, D.C.

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FROM: Susan McGaw for Linda M. Deschere

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COMMENTS:

Re: U.S. Application No.: 09/889,460
Applicant: Jean-Jacques Yon

Dear Mr. Johnston:

Per our conversation, enclosed is a copy of the English Translation filed with the 371 Application on July 16, 2001, along with a copy of the return receipt post card confirming receipt.

I have also attached a copy of the Preliminary Amendment that was originally filed with the application for your convenience.

If you have any questions, please don't hesitate to contact Ms. Deschere or me. Thank you for your attention in this matter.

Sincerely,



Susan McGaw, Paralegal for Linda Deschere

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09/889460

Applicant: YON, et al.	Case No.: 2541-000008
Serial No.: Not yet assigned	Filing Date: Herewith
Title: ELECTROMAGNETIC RADIATION (E.M.R.) HEAT, SENSOR ARRAY AND METHOD FOR MAKING SAME	
Please acknowledge receipt of:	
Application under 35 U.S.C. 371 (18 pgs.), Check for \$860, Express Mail Label EL623558448US, Transmittal Ltr. to the U.S. Designated/Elected Office (DO/EO/US) Concerning a Filing Under 35 USC 371 (in duplicate), Application data sheet (2 pgs.), English translation of International Application as Filed, 4 sheets of Formal Drawings (Figs. 1 - 12), Preliminary Amendment, and this return postcard.	
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**ELECTROMAGNETIC RADIATION (E.M.R.) HEAT, SENSOR ARRAY AND
METHOD FOR MAKING SAME**

DESCRIPTION

5

Technical Field

The present invention concerns an E.M.R. heat detecting device and a manufacturing process for this device.

10

Status of previous techniques

An E.M.R. detector based on the principle of a heat detecting device such as is represented schematically on Figure 1, is generally made up of different subsystems which carry out the four essential functions necessary for the detection of the radiation, i.e.:

15

- an absorption function

The absorption function allows converting the energy of the E.M. incident wave, which is characteristic of the temperature and the emissivity of the environment under examination in a heating phase of the detection structure. The parameters which characterize this function are:

20

- On the one hand the relative absorption (A_r) which defines the ratio of the incident radiation luminance to the luminance actually absorbed by the absorbing structure. A quarter-wave resonant optical cavity facilitates obtaining a relative absorption near to the ideal value of 100%.

25

- On the other hand the fill factor (F_r) which is the ratio between the useful surface actually involved in heating of the detector with the total surface of the latter. In this way one obtains fill factors in the order of 50%.

Optimization of the absorption function consists therefore essentially in maximizing these F_r and A_r parameters.

30

- a thermometer function

The thermometer is an element where one of the physical characteristics is sensitive to temperature. This can be the electrical resistivity

of the material in the case of resistive bolometers, the conductivity of semiconductor devices, residual polarization in the case of a pyroelectric detector, the dielectric constant in the case of a ferroelectric detector, etc. The essential quality factor which characterizes the thermometer function is the relative variation of the physical value observed with the temperature. For a resistive bolometer of R resistance this quality factor is expressed by $dR/R.dT$, i.e. TCR. Optimization of the thermometer consists in maximizing this parameter.

- a heat insulation function

The thermometer is heat insulated from its environment, for example by placing the thermometer on a suspended diaphragm above a substrate, according to an architecture referred to as "microbridge" which is heat insulated on the one hand by integrating the detector in an environment under reduced gas pressure, and on the other hand by interfacing a specific heat insulation device between the microbridge supporting the thermometer and the down-circuit signal processing circuit. The characteristic thermal parameters are, on the one hand the thermal impedance R_{th} which should be maximized so as to improve the sensitivity of the detector, and on the other hand the heat capacity C_{th} which translates the thermal inertia of the thermometer so as to reduce detector response time to an incident flux variation. Response time which is proportional to the result of $R_{th} \times C_{th}$, is typically between several milliseconds and several dozen milliseconds. So as to make a detector both sensitive and at the same time rapid, one should attempt to maximize the effectiveness of the heat insulation and reduce the volume of the thermometer to the minimum. This optimization implies making structures in thin layers.

- the signal processing function:

The signal processing function consists in translating the electric signal issued by the thermometer into a video signal which is usable by camera. This function is realized:

- either by hybridization of the detection circuit on the processing circuit; this initial solution which necessitates treating each

component individually, is incompatible with a process where the technological operations of manufacturing are realized simultaneously on a large number of components assembled flat on a substrate. This initial solution therefore poses the problem of high manufacturing cost.

- 5 • or by mounting the detector on a microbridge suspended above a pre-existing processing circuit. The component made is then called "monolithic". This second solution which enables one to circumvent the problem of manufacturing cost, imposes severe restrictions on the technological processes which make the detection structure - particularly the
- 10 heat budget must be limited so as to avoid downgrading the electrical performance of the processing circuit.

Besides these different functions, moreover one must:

- on the one hand maintain the same mechanical balance between the detector and the processing circuit,
- 15 • and on the other hand provide the transmission of the electric signal originating from the thermometer to the processing circuit.

The figures 2 and 3 represent schematically the layout of the different functions necessary for detection. Figure 2 refers to an architecture where the detector is mounted above the processing circuit, whereas figure 3 represents

20 a configuration where these two elements are side by side.

On these two figures, the following are shown:

- a zone 10 which constitutes the thermometer and corresponds to the active zone of the detector which actually collects the incident photons
- zones 11 which constitute the mechanical support and electrical
- 25 interconnection devices between the detector and the processing circuit
- zones 12 which constitute the detector heat insulation devices
- and a zone 13 which represents the signal processing circuit.

On figure 2, the zone 13 is not represented, as this is located under the detector.

30 The devices 11, 12 and 13 are not involved in detection - to maximize the fill factor one should therefore limit the surface necessary for their realization, by:

- limiting their number to the bare minimum, for example, to two;
- limiting their size, by reducing the length of the heat insulation devices, and therefore their cross-section and thickness so as to retain sufficient heat insulation.

- 5 - choosing the architecture where the detector is mounted on the processing circuit according to a monolithic architecture.

The European EP-0 354 369 patent request describes in this manner an infrared monolithic uncooled detector network of bolometers made on a silicon substrate. The bolometers comprise a silicon dioxide cell of TiN (titanium nitride), a-Si:H (hydrogenated amorphous silicon), TiN and silicon dioxide. The titanium nitride forms the infrared absorber and the resistor contacts, and the amorphous silicon, the resistance with a high temperature resistivity factor. The resistor is suspended above the silicon substrate by metal interconnections and the accompanying processing circuit takes shape in the silicon substrate under the resistor.

To minimize the mechanical deformations of fine structures set up, an initial solution consists in compensating the stresses that develop in a thin layer by the arrangement of an additional layer in contact with this layer.

The second solution consists in reducing the amplitude of the intrinsic stress of materials used by calling upon heat treatment at high temperatures in order to relieve the stresses. But this solution leads to thermally restricting the electronic processing circuit disposed in layers under the detector and to downgrading functionality of the said circuit.

For the time being we shall consider several examples for realization according to previous technology.

Figure 4 represents a perspective view of a unit detector characterized by heat insulation devices 12 of intermediate length.

Structures made, illustrated in figures 5, 6 and 7, show more often than not an outline sketch of three neighbouring detectors 16, 17 and 18 as part of a generally more complex structure, multi-element linear array strip or forming two sizes of detectors.

In the realization illustrated in figure 5, heat insulation is maximized thanks to very long heat insulation devices 12, accompanying the mechanical support and electrical interconnection devices 11. This realization presents the following disadvantages:

- 5 - a reduced active zone 10 due to the bulk of insulation devices, hence a low fill factor;
- a tendency of the part 12 to sag due to its length, which necessitates a thicker diaphragm to ensure the mechanical stiffness.

10 In the realization illustrated in figure 6, the fill factor is maximized by limiting the surface devoted to the heat insulation devices 12; mechanical deformations are limited and a fine structure can be used. But this gives a reduced heat insulation and consequently limited detection sensitivity.

15 In the realization illustrated in figure 7, four physical links are introduced between the detector and the processing circuit, the said links being made up of heat insulation devices 12 accompanying the mechanical support and electrical interconnection devices 11. This realization gives sound mechanical stability of both the structure and the detectors in thin layers. But this has the following disadvantages:

- 20 - a reduced active zone 10 due to the number and bulk of the insulation devices 12 and the mechanical support and electrical interconnection device 11; the fill factor of this type of detector is therefore low;
- a lower heat insulation as heat leakage can spread through eight branches instead of two, hence a sensitivity loss factor of 4.

25 The aim of the invention is to offer a heat detecting device of electromagnetic radiations comprising microbridge heat detectors using the thinnest and flattest suspended active layers possible.

Account of the invention

30 The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices and a signal processing circuit provided by the detectors characterized in that the suspended layers of the microbridges of

two neighbouring detectors are linked together by additional mechanical connections, separate from the mechanical support devices.

Conveniently each mechanical connection is an extension of at least one of the suspended layers of the microbridges.

5 Conveniently each mechanical connection is made in low thermal conductivity material.

Conveniently the mechanical connection(s) is(are) aligned with two mechanical support devices, each belonging to one of two neighbouring detectors.

10 Conveniently the device of the invention can be connected to one or several neighbouring devices by forming a repeat configuration of the said detector following a linear or matrix architecture adapted to the realization of images of electromagnetic wave sources.

The invention concerns more especially the field of infrared detectors based on the principle of a heat detection as opposed to quantic detection, and operating conveniently at ambient temperature.

15 The invention also concerns a manufacturing process of such a device starting with a processing circuit with metallic contact blocks visible on the surface, passivated by an insulating layer in which openings are made at block level. This process comprises the following stages:

- 20 - a reflector on surface of the processing circuit is made by deposit of a metallic coat and definition through photolithography;
- an optical cavity is made by deposit and annealing of a sacrificial layer which is later removed;
- 25 - at least two layers are laid constituting the microbridge, i.e.
 - a layer of heat-sensitive material
 - a conducting coat constituting the detector electrodes
- mechanical support and electrical interconnection devices are made
 - by making an etching next to the contact blocks, of the
- 30 sacrificial layer, of the heat sensitive material and conducting coat

• by laying and etching at least one metallic coat which provides the electrical and mechanical continuity between the contact blocks and the microbridge electrodes;

- the detector electrodes are defined by etching of the conducting coat;
- the heat-sensitive layer, the conducting coat and the optional layers necessary to make the microbridge are etched simultaneously, using a mask to shield an area located between the detectors.

Conveniently, one can attain the following characteristics. The layer of heat-sensitive material is a layer of amorphous silicon. The conducting coat constituting the detector electrodes is a layer of titanium nitride. The metallic coat which facilitates providing the electrical continuity between the electric blocks and the microbridge electrodes is a layer of aluminium. The metallic coat, constituting the detector electrodes, is removed in the areas occupied by the

mechanical connections. After the definition stage of the detector electrodes through etching of the conducting coat, a final layer can be deposited which can be a layer of silicon dioxide, silicon nitride or amorphous silicon.

In an initial variant of the realization, the connection devices are fined down due to their partial etching. Conveniently the conducting coat and the optional layer can be eliminated at the connections.

In a second realization variant, a connection element made in a material other than those already present in the microbridge, with low heat conductivity is inserted on the microbridges entirely isolated from one another - for example silicon nitride or polymer material.

The invention gives the following advantages as a result:

• Effectiveness of incident wave absorption is optimized, due to a better geometrical conformation of the optical cavity which is a quarter-wave resonant cavity.

• The realization of very thin structures, typically 100 nanometers, or even less, is made possible and no longer in the region of 500 nanometers as in devices of previous technology. Implementation of a microbridge in thin layers also means a reduction in thermal inertia of the

detector, and consequently leads to the realization of faster detectors with regard to the modulations of incident flux.

- By favouring the active zone that effectively contributes to the gathering of incident photons, the fill factor is increased. Sensitivity of the detector is therefore increased. Typically the invention results in obtaining a fill factor in the region of 80% which is much higher than the 50% fill factor of the previous technology.

- The mechanical deformations induced by the intrinsic stresses of layers that make up the microbridge are compensated by the mechanical connections. The components made do not therefore require thermal treatment of stress relaxation. The signal processing circuit can thus be conveniently integrated in the detection circuit according to a monolithic structure which is preferable to a hybrid structure in terms of performance and costs.

Brief description of the drawings

Figure 1 shows the schematic diagram of a classic electromagnetic radiation heat detector.

Figures 2 and 3 represent schematically the layout of the various functions necessary for detection.

Figures 4, 5, 6 and 7 show several classic detector structures.

Figure 8 illustrates an initial mode of detection device realization according to the invention.

Figure 9 illustrates a second mode of detection device realization according to the invention.

Figure 10 represents the template of the filter adapted to processing a signal originating from a central detector with two connection elements in the direction of the neighbouring detectors.

Figures 11A and 11B illustrate two cross-section views of a structure of the invention realized according to a preferred mode in the field of infrared detection.

Figure 12 shows the drawing of a mask which makes the cut-out of a microbridge according to the invention.

Detailed statement of the realization modes

5 Following the description, similar elements to those of devices from previous technology described above retain the same references.

 The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors in which the "suspended" layers of the microbridges are linked between each other by
10 a mechanical connection. These suspended layers are layers of the microbridge which are physically isolated from the substrate and held above the substrate by mechanical support devices.

 This device, shown in figure 8, comprises the following elements:

- 15 - two mechanical support and electrical interconnection 11 devices per detector;
- two heat insulation 12 devices per detector;
- an active zone sensitive to radiation 10 per detector;
- two mechanical connections 15, 15' which link the central detector 16 mechanically to neighbouring detectors 17 and 18, and which prevent
20 attenuation of the microbridge zones the furthest away from the mechanical support devices 11.

 Each mechanical connection 15, 15' can be an extension of at least one of the microbridge suspended layers. It can be made of material with low thermal conductivity.

25 The invention device provides reinforced mechanical stability through specific support devices which ensure mechanical continuity between each detector and its nearest neighbours. The realization of a repetitive configuration of the invention detector according to a linear or matrix architecture leads to an assembly of detectors referred to as connected
30 whose mechanical resistance is improved.

 Thermal intermodulation IMT which is shown by an electrical intermodulation between neighbouring detectors, is perfectly defined by the

respective geometrical dimensions of the heat insulation devices 12 and the mechanical connections 15 and 15', and because of this fact, can be corrected. Foremost one has the following relations:

$$\text{IMT} = dT/dT_v = R_{th} / (R_{th} + 2.R_{cx})$$

5 $R_{th} = L_1 / (\lambda_1 . W_1 . E_1)$

$$R_{cx} = L_2 / (\lambda_2 . W_2 . E_2)$$

with:

- dT heating of a detector, induced through the mechanical connections, by dT_v heating of the neighbouring detector receiving the infrared flux;
- R_{th} thermal impedance of the heat insulation devices 12;
- R_{cx} thermal impedance of the mechanical connections 15 and 15';
- λ_1 , L₁, W₁, E₁ being respectively the heat conductivity, length, width and thickness of the heat insulation devices 12, and λ_2 , L₂, W₂, E₂ represent the same parameters relative to the mechanical connections 15, 15'.

15 In this particular case where devices 12, 15 and 15' have the same cross-section and an identical heat conductivity, the intermodulation IMT between detectors is expressed:

$$\text{IMT} = L_1 / (L_1 + 2 . L_2)$$

The intermodulation between detectors can therefore be limited and adjusted depending on the targeted application, thanks to a competent drawing of devices 12, 15 and 15'. Typically, values in the region of 20% which facilitate making an infrared retina of good quality, can be obtained for connections 15, 15' with double heat insulation arm length 12, as illustrated in figure 9.

One can also totally remove the intermodulation introduced by the connections by carrying out a suitable mathematical processing of the signal originating from the detectors, by inverse filtering of the uncompensated signal contaminated with intermodulation by a filter whose template is defined

by the rate of intermodulation. Figure 10 thus represents the pattern of a filter adapted to processing of a signal originating from a central detector 16 with two connection elements to the neighbouring detectors 17 and 18, and characterized by an intermodulation rate of 10%.

5 Now we will describe several realization modes for the invention device.

Figures 11A and 11B show two cross-section views of a structure made according to a preferred mode for the invention, representing two neighbouring detectors 16 and 17. The first cross-section (figure 11A) is made
10 outside the connection devices 15 and 15', whilst the second (figure 11B) cuts across the latter.

The manufacturing process of such a device starts with a processing circuit 19 already made, obtained according to known techniques, for example microelectronics on silicon, with metallic contact blocks 20 visible on the
15 surface which facilitate making the electrical connections between the detectors and the processing circuit inputs. These contact blocks 20 are usually passivated with an insulating layer 21 in which openings have been made around the blocks.

A metallic coat 22, in aluminium for example, is conveniently laid and
20 defined by photolithography in order to make an infrared reflector on the surface of the processing circuit 19. The role of this reflector is to optimize absorption of the infrared wave by improving the effectiveness of the quarter-wave resonant cavity constituted by the reflector 22, the microbridge 29 and the space between these two components.

25 A sacrificial layer 23, made of polyimide for example, is then spread and eventually annealed. This layer on which the microbridge is mounted and which is removed ultimately, facilitates making the said cavity. The thickness of this layer is usually 2.5 micrometers which facilitates making a sensitive detector in a wavelength range in the region of 10 micrometers.

30 There are at least 2 layers constituting the microbridge, which are later laid on the sacrificial layer 23:

- a layer 24 of heat-sensitive material which can be amorphous silicon laid following a classic process;

- a conducting coat 25 constituting the detector electrodes which can be titanium nitride laid by reactive sputtering.

5 The mechanical support and electrical interconnection devices whose realization will be described hereafter, are those of a microbridge in the field of infrared. The practical stages to obtain them are specific, independent of previous stages described and can be replaced by practical stages of other support and interconnection devices.

10 These mechanical support and electric interconnection devices are thus obtained by making:

- an etching, according to photolithographical processes, of layers 23, 24, and 25 up against the contact blocks 20;

15 then, the deposit of one or several metallic coats 26 which provide better electrical and mechanical continuity between the contact blocks and electrodes of the microbridge. This metallic coat is aluminium, for example. This coat 26 is defined and etched according to usual processes, so as to limit the bulk of these interconnection devices to the one surface essential for sound recovery of contact with the electrode 25 of the detector.

20 Then the electrodes of the invention device are defined by etching of the metallic coat 25 according to a configuration adapted to the required electrical characteristics for the detector. This coat 25 is conveniently removed from the zones which will be later occupied by the connection components, so as to avoid electric short-circuits between detectors and
25 improve thermal impedance of the connections.

 A final layer 28 can also be laid on the microbridge 20 to obtain a symmetrical structure less sensitive to the internal stresses which develop in the layers, by compensating for "bimetal" type phenomena. This layer 28 can either be an electrically active material, possibly of the same type as the heat
30 sensitive material 24, or an electrically neutral material which can be of low heat conductivity as it can increase thermal leakage of the microbridge.

Preferably silicon dioxide, silicon nitride or even amorphous silicon is therefore used.

A final photolithographical level facilitates definition of the detector perimeters by simultaneous etching of layers 24, 25 and 28 which results in;

- 5 - isolating the detectors from one another;
- defining the heat insulation devices 12 cut in the microbridge 29 itself, in order to make a component of reduced cross-section, of considerable length and sound mechanical resistance between the mechanical support and electrical interconnection device on the one hand, and the detector on the
- 10 other.

Connections between detectors can also be made during this last stage. By using a suitable sketching mask, the etching of layers 24, 25, 28 shields a specific area of limited extent and located between the detectors, the material shielded constituting the connection devices. The shielded zone

15 is small in cross-section, typically between 0.5 and 3 micrometers wide for a thickness equal to that of the microbridge. The geometrical ratio of the connection to the total perimeter of the detector is therefore very limited which facilitates making detectors of low thermal intermodulation.

Now several variations of the invention device will be considered successively, with the aim of limiting thermal intermodulation between

20 detectors, and at the same time providing satisfactory mechanical resistance.

An initial variant of the invention consists in fining down the connection devices due to a partial etching of the latter. One can either etch one of the layers of the connection elements entirely, or appreciably fine down one of its

25 components by controlling etching time. As an example, the metallic coat 25 and the optional layer 28 can be removed at the connections without in fact limiting mechanical resistance of the whole in any way. This process of local etching calls upon the use of a specific mask and usual photolithography techniques.

30 A second variant consists in adding a connection element made in a material if necessary different from those already present in the microbridge and chosen for its favourable thermal characteristics on microbridges which

are entirely isolated from one another, for example silicon nitride or polymer materials with low thermal conductivity. Polymers of the PVDF type are especially favourable as they have a lower thermal conductivity to that of silicon dioxide. The usual depositing techniques, in particular PECVD, LPCVD
5 deposits, cathode sputtering, spreading of solution containing a liquid precursor, etc. can be used.

The invention can also be applied to connection devices of geometrical shapes other than rectangular. A design that maximizes the length is advantageous as it limits intermodulation between detectors. As an example,
10 figure 12 shows the design of a mask which makes the cut-out of the microbridge according to the notion of the invention and which maximizes the length of connections.

CLAIMS

1. Electromagnetic radiation heat detecting device consisting of at least two microbridge detectors with mechanical support devices, with a signal processing circuit provided by the detectors characterized in that microbridge
5 suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15'), separate from the mechanical support devices.

2. Device according to claim 1, in which each mechanical connection (15, 15') is an extension of at least one of the suspended microbridge layers.

10 3. Device according to claim 1, in which each mechanical connection (15, 15') comprises a material with low thermal conductivity.

4. Device according to claim 1, in which the mechanical connection(s) (15,15') is (are) in line with two mechanical support devices (11), each belonging to one of two neighbouring detectors.

15 5. Device according to any one of the preceding claims in which the said device forms a repetitive detector configuration according to a linear or matrix architecture.

6. Manufacturing process of a device according to any one of the preceding claims, characterized in that by starting from a processing circuit
20 (19) with metallic contact blocks (20) visible on the surface, it comprises the following stages:

- a reflector (22) is made on surface of the processing circuit through deposit of a metallic coat with definition through photolithography;
- an optical cavity is made through deposit of a sacrificial layer (23)
25 which is later removed;
- at least two layers constituting the microbridge are laid, in other words
 - a layer of heat-sensitive material (24),
 - a conducting coat (25) constituting the detector electrodes;
- the mechanical support and electrical interconnection devices are
30 made

- against the contact blocks, by carrying out an etching of the sacrificial layer (23), the layer of heat sensitive material (24) and the conducting coat (25),
- by depositing and etching at least one metallic coat (26) which provides the electrical and mechanical continuity between the contact blocks (20) and the microbridge electrodes (25);

5 - the detector electrodes are defined by etching the conducting coat (25);

10 - the layer of heat-sensitive material (24), the conducting coat (25) and optional layers (28) are etched simultaneously using a mask to shield a zone located between the detectors;

7. Process according to claim 6, in which the layer of heat-sensitive material (24) is a layer of amorphous silicon.

15 8. Process according to claim 6, in which the conducting coat (25) constituting the detector electrodes is a layer of titanium nitride.

9. Process according to claim 6 in which a layer of aluminium (26) is deposited which will provide electrical continuity between the electric blocks (20) and the microbridge electrodes (25).

20 10. Process according to claim 6, in which the metallic coat (25) constituting the detector electrodes, is removed in the zones occupied by the mechanical connections (15, 15').

11. Process according to claim 6 in which, after the definition stage of the detector electrodes by etching of the conducting coat (25), a final layer is deposited (28).

12. Process according to claim 11 in which this last layer (28) is a layer of silicon dioxide, silicon nitride or amorphous silicon.

13. Process according to claim 6 in which the mechanical connections (15, 15') are fined down due to partial etching of the connections.

30 14. Process according to claim 13 in which the conducting coat (25) and the last layer (28) are removed at the connections.

15. Process according to claim 6 in which a connection element made in a material with low thermal conductivity is added on the microbridges entirely isolated from one another.

16. Process according to claim 15 in which the material with low
5 thermal conductivity is silicon nitride or polymer material.

ABSTRACT OF THE DISCLOSURE

5 The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices with a signal processing circuit provided by the detectors in which microbridge suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15') separate from the mechanical support devices.

10 The present invention equally concerns the manufacturing process of such a device.

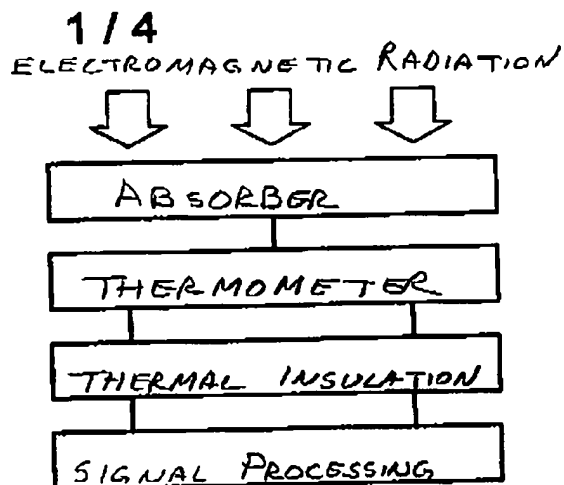


Fig. 1

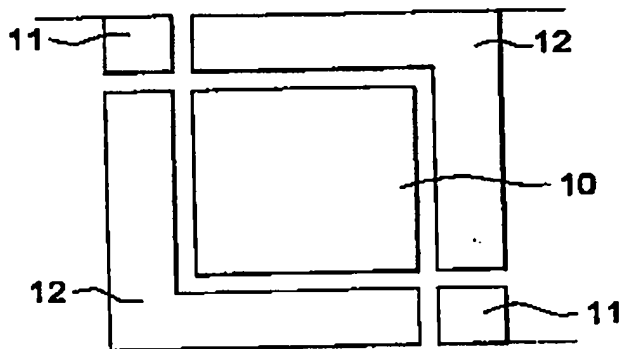


Fig. 2

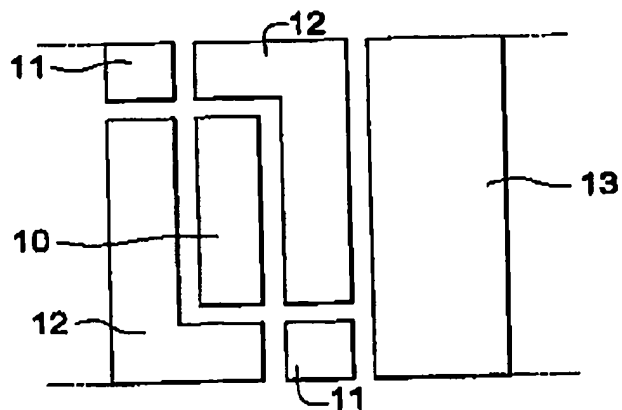


Fig. 3

2 / 4

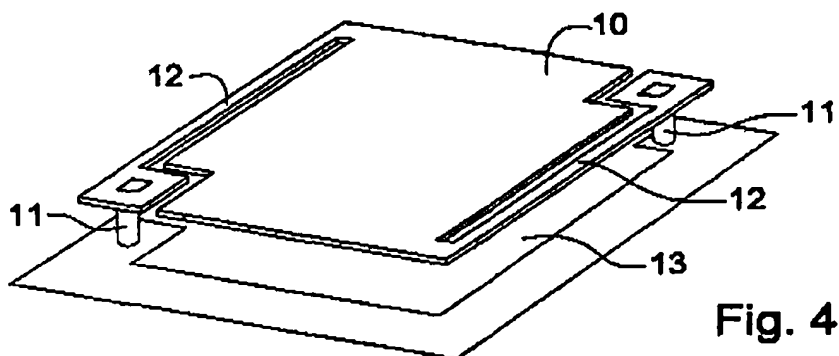


Fig. 4

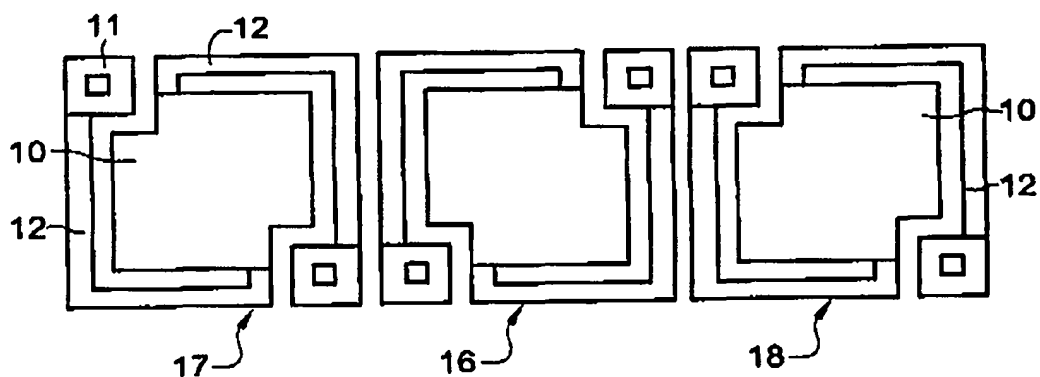


Fig. 5

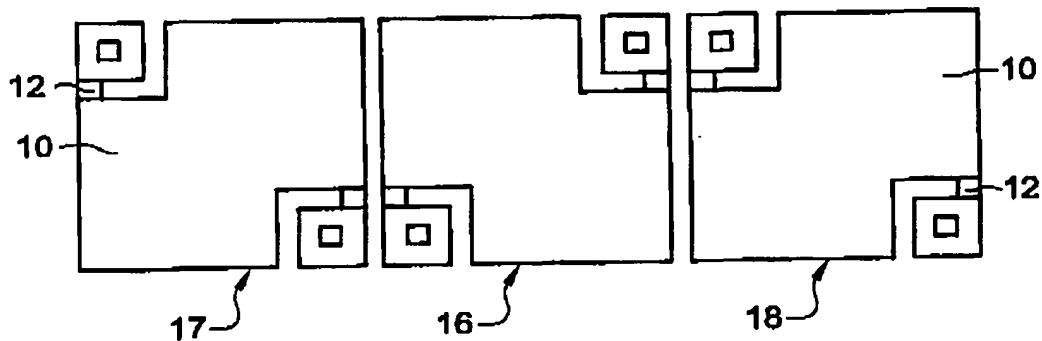
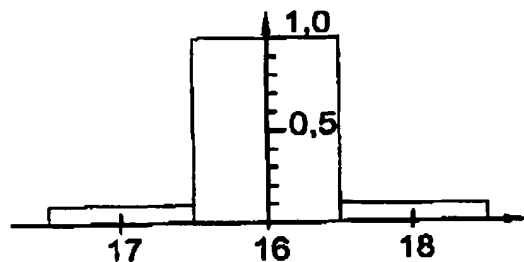
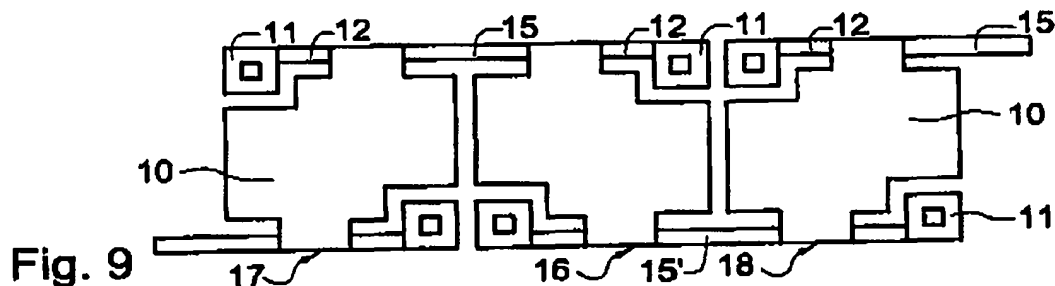
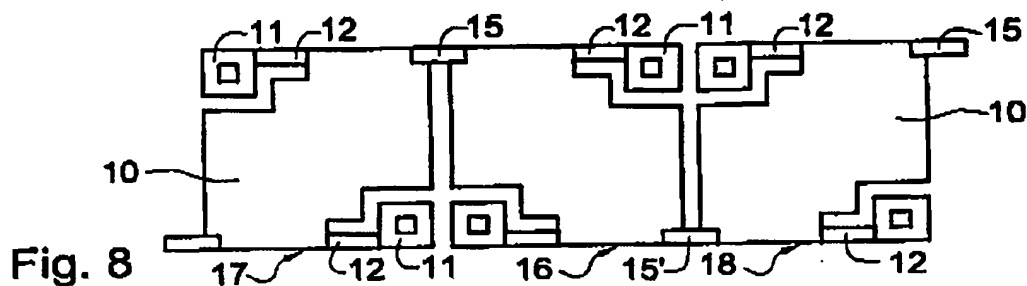
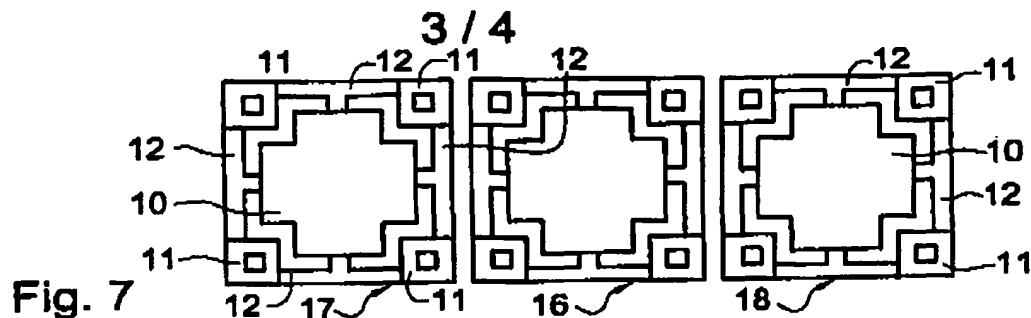


Fig. 6



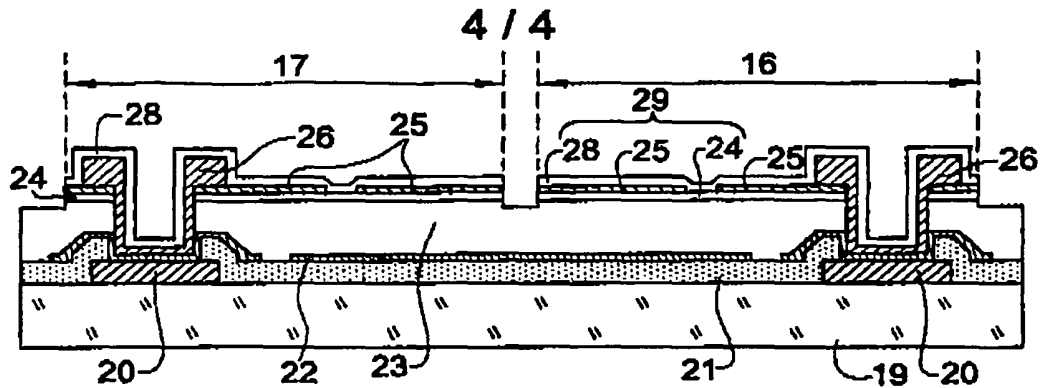


Fig. 11A

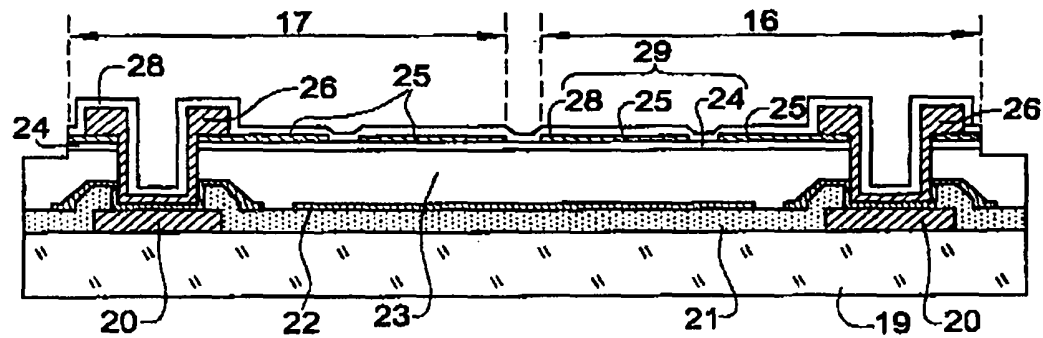


Fig. 11B

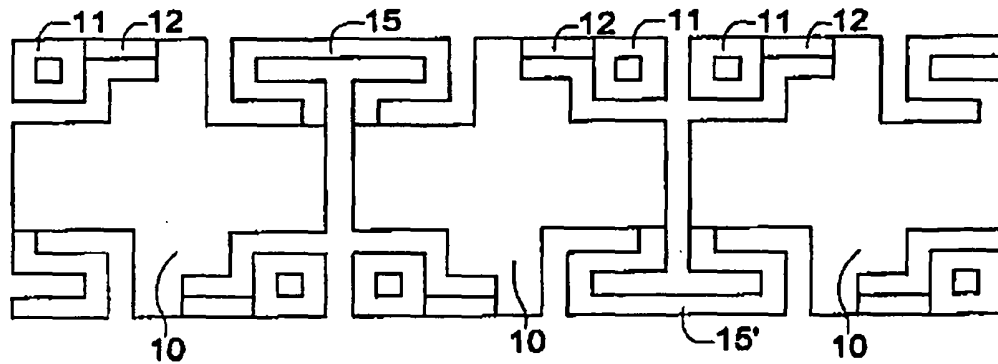


Fig. 12